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Guilford's Structure of Intellect Model and Model of Creativity: Contributions and Limitations

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ABSTRACT: J. P. Guilford has had an enormous influence on the psychology of creativity. In many ways, he is the father of modern creativity research. Yet his conception of creativity was, we suggest, flawed in certain respects. In this article, we discuss both the strengths and limitations of Guilford's approach to creativity.

A politician was told by a powerful constituent that he really ought to back an important bill that would be of great value to the constituent. The politician, eager to please, agreed with the constituent and told him, "You're right." The constituent was pleased.

Shortly thereafter, another powerful constituent—a bitter rival of the first—approached the politician to seek his opposition to the same bill. The politician, eager to line up the support of this constituent as well, agreed and told him, "You're right." This constituent, too, was pleased.

Unfortunately for the politician, the two constituents talked to each other, each eager to inform the other of the support he had for his position. When they discovered that the politician had said he was supporting both of them, despite their opposing views, the two constituents angrily confronted the politician together, bitterly informing him that he could not possibly support them both. The politician, ever eager to please, smiled and replied, "You're right."

The situation in the field of research on creativity has come to be rather similar to that of the constituents facing off the politician, except that in this case, the politician appears to be the natural order of things. We say "appears to be" because the natural order of things no more supports multiple conflicting truths than did the politician. However, the field of creativity research, as well as that of intelligence research, has stagnated throughout much of its history because operationalizations of theories have been constructed and then construed in such a way so that the data appeared to support the theorist almost without regard to how they came out. The most obvious example in the history of the field is probably the support that J. P. Guilford obtained over the years for his Structure of Intellect (SI) model, which has served as the basis for a major model of creative thinking.

Guilford's SI Model

Guilford's (1967; Guilford & Hoepfner, 1971) SI model became one of the most well-known models of intelligence ever to be proposed. To understand Guilford's model of creativity, one first must understand his general model of intelligence, as Guilford viewed creativity as part of intelligence.

The SI model is an extension of Thurstone's (1938) theory and incorporates all 7 of Thurstone's primary mental abilities (verbal comprehension, verbal fluency, number, spatial visualization, memory, perceptual speed, and reasoning). However, it splits the primary mental abilities and adds new abilities so that the number of factors is increased from 7

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to 120. Whereas Thurstone permitted factors to be correlated, Guilford hypothesized that the factors are independent.

According to Guilford (1967), every mental task includes three ingredients: an operation, a content, and a product. There are five kinds of operation: cognition, memory, divergent production, convergent production, and evaluation. There are six kinds of product: units, classes, relations, system, transformations, and implications. Finally, there are four kinds of content: figural, symbolic, semantic, and behavioral.

Because the subcategories are independently defined, they are multiplicative, so that there are $5 \times 6 \times 4 = 120$ smaller cubes. Guilford (1982) later increased the number to 150 and still later to 180 (Guilford, 1983). Each dimension of the cube corresponds to 1 of the 3 categories (operation, content, product), and each of the 120 (or 150 or 180) possible combinations of the 3 categories forms 1 of the smaller cubes.

Guilford and his associates have devised tests that measure many of the factors required by the model. (Guilford & Hoepfner, 1971, reported that the number of demonstrated SI abilities was 98.) We can consider here only a few of the many examples, as there are so many abilities and usually at least two tests to measure each ability. Cognition of figural relations, for example, is measured by tests such as figure analogies or matrixes. Memory for semantic relations is measured by presenting examinees a series of relations, such as "Gold is more valuable than iron" and then testing retention in a multiple-choice format. Evaluation of symbolic units is measured by same–different tests, in which participants are presented with pairs of numbers of letters that are either identical or different in minor details. Participants then have to mark each pair as either same or different.

Creativity, in Guilford's (1975) SI, is localized in particular in certain aspects of the model. In particular, the process of divergent production is most important to creativity. It may be combined with a product and a content category in 24 different ways. These 24 combinations of process, product, and content are collectively referred to as *divergent thinking*. Transformation skills are also important to creative thinking, according to Guilford.

Guilford (1975) construed creativity as a form of problem solving. Guilford's model of creativity goes beyond his SI model. He suggested that there are four main kinds of problem-solving abilities (see also Ochse, 1990):

1. *Sensitivity to problems,* or the ability to recognize problems.
2. *Fluency,* which encompasses
   a. *Ideational fluency,* or the ability rapidly to produce a variety of ideas that fulfill stated requirements.
   b. *Associational fluency,* or the ability to generate a list of words, each of which is associated with a given word.
   c. *Expressional fluency,* or the ability to organize words into larger units, such as phrases, sentences, and paragraphs.
3. *Flexibility,* which encompasses
   a. *Spontaneous flexibility,* or the ability to demonstrate flexibility.
   b. *Adaptive flexibility,* or the ability to produce responses that are novel and high in quality.

Guilford's theory was a major presence in American psychology through the early 1970s. It has shaped much research on divergent thinking (e.g., Mumford & Gustafson, 1988; Runco, 1986). Today, it is not. What happened? We divide our discussion into three parts: problems of theory, problems of measures, and contributions.

Problems of Theory

Problems Specific to Guilford's Theory

Guilford's theory today is considered by many psychologists to be somewhat of a theory of the past. We argue that although the details of the theory are probably wrong, nevertheless, the theory has made important and lasting contributions. Why? There are several reasons.

Some investigators found the large number of factors in the Guilford model to be a reductio ad absurdum of the whole factorial approach (e.g., Eysenck, 1967), but nevertheless, Guilford seemed to have the quantitative support of numerous factor-analytic investigations behind him. As we show, however, the support was not really credible.

Guilford (1974) called the need for rotation of factors "the most serious weakness" (p. 498) of the factor-analytic method. The crux of the problem is that whereas the factor space is unique, the orientation of axes is not. The axes may be rotated in an infinite number of ways, each of which defines factors along different dimensions. The different dimensions have different psychological implications.

For example, an unrotated solution typically will support a theory of a general factor followed by bipolar group factors and possibly specific factors. Indeed, the algorithms usually used practically guarantee a general factor, as the maximal possible variation is placed into the first factor. Rotation to simple structure often will support a theory of group or multiple factors in the absence of a general factor. Subjective rotation to minimize discrepancies between predicted and observed factors can yield still different results.

Although most American psychologists have used objective rotation to simple structure, Guilford's (1974) "experience showed that although simple structure is a useful guide, it is by no means sufficient if we want logical psychological meaning" (p. 498). Simple structure, however, is no panacea, because there is no particular a priori justification for this form of rotation over any other, and it fails to elucidate the complex hierarchical structures that can underlie human abilities (Carroll, 1993; Horn, 1994).

In the course of his career, Guilford (1974)

> actually tried out just about every objective computerized method that existed, both orthogonal and oblique, with the same sets of data. The general results were the same: Factors were neither nicely interpretable nor were they invariant from one method to another. This is a fact of life that those who factor analyze must face. (p. 499)

Facing this fact, Guilford turned to subjective rotation, the most widely used of which are a class of "Procrustean" algorithms (e.g., Cliff, 1966; Hurley & Cattell, 1962; Schonemann, 1966). (Procrustes was the Attican giant who seized travelers and cut off their legs or stretched them until they fit an iron bed to which he had tied them.) In this form of rotation, the investigator rotates the obtained principal-components (or principal-factor) solution into maximum congruence with a target matrix specified by one's theory. On its face, therefore, the method would seem to have the advantage of being theory based. However, these methods also have a drawback, that

> aiming of axes in the directions of selected tests involves forcing of data toward a better fit to theory than is justified by the data. But knowing from experience how stubborn coefficients of correlations are as data and also the principal-factor coefficients derived from them, there was not a great deal of concern on that score. (Guilford, 1974, p. 499)

Unfortunately, there was a problem and there should have been concern. The subjective method of rotation Guilford used was flawed in ways that Guilford was unaware of. Horn (1967; Horn & Knapp, 1973) showed that if one utilized random data and rotated the original factor pattern matrix into maximum congruence with the target matrices specified by Guilford's theory, one would get quite strong support for the theory. Moreover, if one utilized real data (Guilford's) and then rotated the obtained data into maximum congruence with random target matrices, one would again get quite strong support for the theory. One could only conclude, therefore, that the factorial support for Guilford's theory was wholly artifactual. Nature was supportive of Guilford's theory no more than the politician was supportive of the ideas of both of his constituents. Indeed, Procrustean rotation would support any theory.

In Horn and Knapp's (1973) words,

> The support provided for such arbitrary theories is quite comparable to that put forth as providing support for SI theory. This pseudo-support for a theory can be obtained (a) with variables that are not random, (b) under a requirement that factors remain orthogonal, (c) when factor coefficients remain generally positive, (d) under a requirement that loadings be .30 or larger to be regarded as "significant," and (e) in samples as large as are customarily used in psychological research. (p. 42)

Horn and Knapp (1973) correctly pointed out that their results do not conclusively disconfirm Guilford's theory. The Horn–Knapp factors will probably not replicate as well as Guilford's, and no single experiment or set of experiments is likely to undermine a theory entirely. But the data suggest that what Guilford interpreted as confirmation of his theory was not. Nevertheless, there are at least some studies that favor aspects of Guilford's model (Bachelor & Michael, 1991; Bachelor, Michael, & Kim, 1994; Guilford, Merrifield, Christensen, & Frick, 1961; Michael & Bachelor, 1992). Today, more sophisticated confirmatory and other techniques have replaced those used by Guilford (e.g., Embretson & McCollam, 2000).

Problems General to Other Psychometric Theories as Well

There are problems that are general to all psychometric theories, not just Guilford's. What are some of the main such problems?

Rotation revisited. The rotation dilemma has been the bane of other theorists as well. Of course, not all psychometric theorists of intelligence or creativity have used subjective rotations in their factor analyses. On the contrary, most have used objective rotations. Yet, their interpretations of the data have been problematical as well, starting with those of Spearman, the inventor of factor analysis. Spearman (1904) claimed that his factor analyses supported the existence of a general factor and specific factors underlying his data. However, as has become obvious since then, any unrotated factorial solution will give the appearance of a general factor in some degree, because the first common factor (or principal component) maximizes the variance that can be extracted from the data.

Given that there will always be some degree of generality in that factor, at what level of percentage of variance accounted for does one state that there is a true general factor? Is one satisfied with 10%, 30%, 50%, 70%, or what? As there is no preset criterion, investigators in favor of a general factor essentially can use whatever percentage they wish and thereby interpret their data as supportive of a general factor. At the same time, those opposed to a general factor can come to the reverse conclusion.

Thurstone (1938), in fact, did come to a different conclusion, arguing that simple-structure rotation, which maximizes the variation in loadings in the columns of the factor matrix and thus results in variables tending to either load or not load on a given factor, is the correct rotation to use. Carroll (1993) agreed, believing that the issue is largely resolved. Yet, mathematically, any one of the infinite possible rotations is as good as any other, and there is no compelling psychological argument for why a simple-structure rotation or any other rotation is psychologically "best." The result, as we have seen in years of factor-analytic research, is that researchers can argue for a wide variety of solutions, each claiming that nature, like the politician, supports his or her position.

Difficulty in discovering or explicating process. Factor analysis provides no way to discover or explicate the processes that in combination constitute intelligent behavior unless there are substantial individual differences in these processes; even then, the identification of processes is very indirect. Thurstone (1947) realized that the goal of research into the nature of mental abilities should be the understanding of process. He pointed out that "the factorial methods were developed for the study of individual differences among people but the individual differences may be regarded as an avenue of approach to the study of the processes which underlie these differences" (p. 55). Unfortunately, the avenue of approach has had little traffic, perhaps because "it is difficult to see how the available individual differences data can be used even as a starting point for generating a theory as to the process nature of general intelligence or of any other specified ability" (McNemar, 1964, p. 881). Nevertheless, we agree with Thurstone (1947) that exploratory factorial methods are useful in hypothesis generation and explanation.

The problem is that factor analysis as it is traditionally used is capable only of analyzing interitem structure in a test, whereas a direct process analysis would require analysis of intraitem structure. It would require elucidation of the steps involved in the solution of a single item. Factor analysis "deals only with the end products of human thinking and behavior, and throws little light on how these products come about in individual human beings" (Vernon, 1971, p. 9). Because of this fact, factorial studies do not "enable us to decide what are the basic components of mental organization" (Vernon, 1970, p. 100).

Interindividual nature of analysis. The cognitive components of abilities are intraindividual—they exist within individual subjects. Factor analysis, however, is generally interindividual—it analyzes patterns of individual differences across participants. Because individual differences are meaningless in the context of one individual, it is not clear how factor analysis could enable us to discover what the cognitive components within an individual are. We do not deny here the role of context, which of course is important. But the cognitive components must be understood internally.

Although certain modes of factor analysis could be used intraindividually, it has not been shown that they could discover underlying components of abilities. As

a result, it is not clear how factor analysis can tell us much about intraindividual variation.

The effects of the binding of factor analysis to individual differences can be illustrated with reference to five hypothetical mental ability tests that require eight hypothetical mental components for their solution.

Test 1:
A, b, C, C', d

Test 2:
A, b, C, C'

Test 3:
A, b, C, C', d

Test 4:
A, b, d, E

Test 5:
A, b, F, F'

Here, tests are represented by numbers, and the mental components underlying them by letters. Capitalized letters—A, C, C', E, F, F'—represent components that are sources of individual differences in test performance. Some of these sources of individual differences are very highly correlated with each other, and these correlated sources are represented by primed and unprimed pairs: C' and C, F' and F. Other mental components are not sources of substantial individual differences in the sample of the population to which the tests are given, although they might show individual differences in some other more heterogeneous sample. The sample might be composed of college sophomores taking introductory psychology, although the population of interest is somewhat wider than that. These components (in which there are unsubstantial levels of individual differences) are represented by lowercase letters—b and d.

The correlation matrix from the tests is factor analyzed, and the outcome will depend for its interpretation on the rotation used (if any). However, one idealized, psychologically interpretable outcome would consist of a general factor, a group factor, and specific factors. Yet, these factors will not represent individual cognitive components. At best, they will be confounded.

There will be just one general factor, Component A. Component b will not be represented by a general factor, or any factor, because although it is general, it cannot be identified due to its constant value across participants. Factors and factor scores are standardized so that any constants are removed.

The group factor will include both components C and C', because although they are separate components, they are highly correlated enough across participants so as to be inseparable through factor analysis. It should be noted that in spite of this high correlation across participants, C and C' may be weakly correlated or even uncorrelated across tasks. "Group" Component d will not be accounted for at all because of the absence of individual differences.

Component E will emerge as a separate specific factor, but F and F' will be confounded, and if there are 1s in the diagonal of the corrrelation matrix, error variance will be confounded with systematic specific variance from Component E and from Components F and F'.

The purpose of this analysis is to show that factors are not representations of the components of abilities. The analysis is both hypothetical and idealized. With real data, even the confounded components would not emerge so cleanly. Furthermore, even in the ideal situation, this scheme is only one of an infinite number possible through rotation of axes. Rotation would very likely result in some or all components being split up between factors, so that not only would components be confounded, but they would be fragmented as well. Factor analysis provides no way of isolating the components or assuring that they will remain intact.

Problems of Measurement

Guilford devised a number of tests of creativity, based on his SI theory. The tests centered on divergent production. For example, a test of divergent production of semantic units might require examinees to name things quickly that are white and edible. Another test might require individuals to think of unusual uses of a paper clip.

Although Guilford is the father of this kind of creativity testing, it should be noted that the test that has achieved the most fame is that of Torrance (1974). This test is based on Guilford's theory and thus can be seen as a fairly strict extension of the framework proposed by Guilford.

Ochse (1990) summarized some of the main problems with the SI-based tests. We draw on her discus-

sion. One of the main ones is that when scores on the Guilford-type tests have been correlated against other ratings of creativity, the correlations are generally low (e.g., Beittel, 1964; Merrifield, Gardner, & Cox, 1964; Ochse, 1990; Piers, Daniels, & Quackenbush, 1960; Plucker & Renzulli, 1999; Skager, Schultz, & Klein, 1967; Torrance, 1962; Wallach & Kogan, 1965; Yamamoto, 1964). Moreover, as pointed out by Wallach and Kogan (1965) and others, the correlation between scores on Guilford-types of tests of creativity and various criteria of adult creativity are close to zero (Gough, 1964; MacKinnon, 1962; Taylor, Smith, Chiselin, & Elison, 1961). Elliot (1964) suggested that correlations are obtained only when the criteria closely resemble the predictors. However, as Amabile (1996) and others (e.g., Sternberg, 1988) pointed out, the kinds of materials used on Guilford-type creativity tests bear little or no resemblance to the types of tasks used to assess creativity in adults.

On the contrary, divergent thinking of the type measured by Guilford just does not seem to correspond well to the kind of thinking required for serious creativity (Austin, 1978; Cattell, 1971). As a result, it is not surprising that the tests just do not predict adult creativity in actual work domains.

It is surprising that Guilford (1975) himself was not concerned. He stated that "so long as we maintain the role of scientist we are not concerned with whether the products [of creative thinking] are socially valuable" (p. 37). Yet, in losing social value, the products also lose relevance to what they are supposed to predict.

Other approaches to measuring creativity have been taken, of course (see Sternberg, 1988, 1999). For example, Sternberg and Lubart (1995), in testing their investment theory of creativity, measured creative thinking in four domains: story writing, artwork, advertising, and science. Like Guilford (1967), we used divergent-production tasks, although ones we believe may have allowed a more substantial kind of creativity than in the case of Guilford's tasks. In the story-writing domain, participants were given titles for compositions such as "The Keyhole" or "The Octopus's Sneakers" and were asked to write very short stories based on 2 of 12 options. In the art domain, participants were asked to draw options such as "earth from an insect's point of view" and "the beginning of time." In the advertising domain, participants were asked to do advertisements for boring products such as doorknobs or bowties. In the science domain, they were asked to speculate on issues such as how we might be able to detect extraterrestrial aliens among us who were seeking to escape detection.

Products were rated for novelty and quality. Sternberg and Lubart (1995) found that, although scores on tests across domains correlated, the correlations were generally in the low to moderate range, suggesting some degree of domain specificity in creativity. They also found that scores for five resources—intelligence, knowledge, thinking styles, personality, and motivation—were predictive of creative performance.

The theory of Sternberg and Lubart (1995), like some other theories (e.g., Amabile, 1996; Csikszentmihalyi, 1996; Gardner, 1993; Gruber & Barrett, 1974) incorporates affective and motivational elements as well as cognitive ones. It may be that no cognitive test will ever predict creative performance very well because such a test does not take into account affective and motivational variables. Ultimately, then, a more satisfying approach may be to consider creativity not as a subset of intelligence, but as overlapping with it (see Sternberg & O'Hara, 1999).

Contributions

For all its problems, Guilford's theorizing has made a number of important and lasting contributions. Arguably, these contributions outshine the flaws. First, Guilford was among the first to define intelligence very broadly. Modern theories that take a broad view of intelligence (e.g., Gardner, 1983, 1999; Sternberg, 1985, 1997) owe Guilford a debt. Second, the interpersonal and intrapersonal factors of Gardner's theory and the creative and practical facets of Sternberg's theory both were adumbrated by Guilford's behavioral dimension. Third, Guilford recognized the importance of precise empirical testing of theories. Although his tests did not all prove to be valid, they represented a serious effort at empirical validation, an attribute some modern theories (e.g., Gardner's) lack. Fourth, the theory was specified with sufficient detail and precision that it could be tested and, to a large extent, disconfirmed. No theory lasts forever, and theorists perform a service when they specify their theories in sufficient detail to allow disconfirmation. Finally, Guilford (1950, 1970) resparked interest in creativity at a time when the field was moribund.

Conclusions

The problem in the fields of creativity and intelligence is that researchers, and Guilford especially, have concentrated on confirmation rather than disconfirmation of their theories. This is a normal human tendency (Nisbett & Ross, 1980). The result has been that all the theories appear, to the investigators, to be "correct." Nature truly agrees with all of the different people in the field of mental abilities no more than the politician cited at the beginning of this article agreed with both of his constituents. Until we all do research that allows and even encourages our beliefs to be disconfirmed—in other words, until we act like scientists (Popper, 1959)—we are likely to feel as happy as the politician's constituents, each of us convinced that we alone possess the truth that so many of the dullards in the field just cannot or do not want to appreciate. Meanwhile, the politician knows better.

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